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SPECTROSCOPIC PROPERTIES OF Nd^{3+} IN ORTHORHOMBIC δ-BiB_3O_6 CRYSTAL

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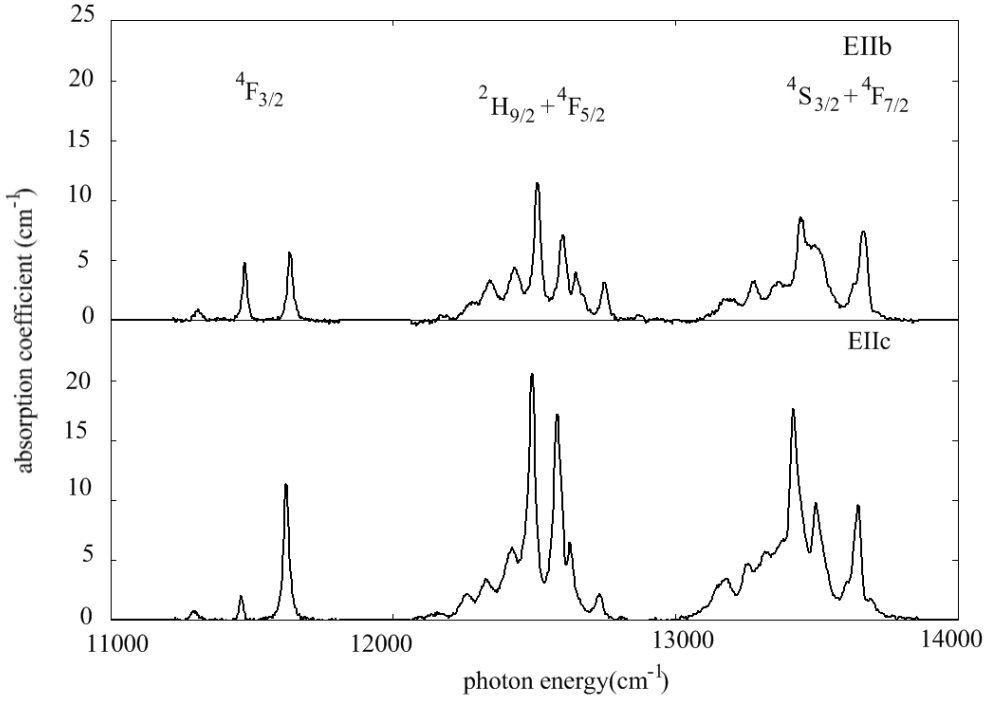
В данной статье описывается метод анализа спектральных свойств иона неодима в дельта - триборате висмута, а также приводятся результаты этого анализа.

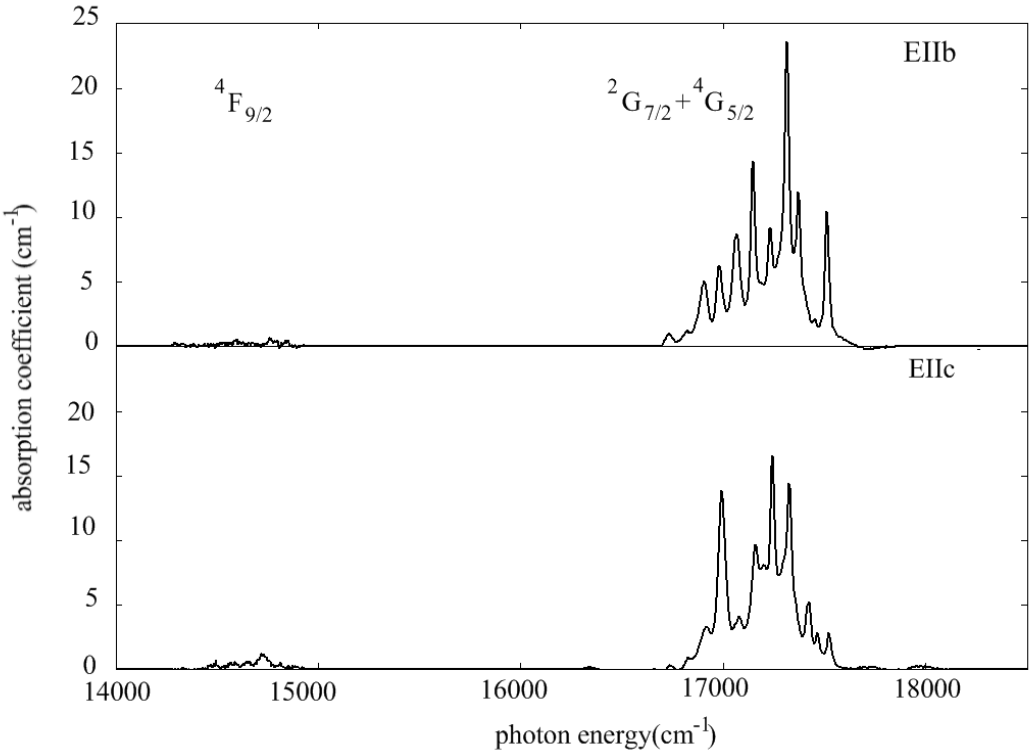
Monoclinic bismuth triborate α-BiB_3O_6 (α-BiBO) is a very promising nonlinear crystal. The studies of doping monoclinic bismuth triborate with rare earths were done in order to obtain new laser materials, possibly self-doubling ones, for diode pumped lasers. But these studies revealed limited extent of doping that is insufficient for laser applications. Later, new polymorphs of bismuth triborate, including orthorhombic δ-BiB_3O_6 (δ-BiBO) were discovered. δ-BiBO has denser packing of crystal structure, but surprisingly we were able to obtain large Nd number density in this crystal. Later studies have shown that phase matching conditions in delta BiBO are favorable for frequency doubling of radiation in the region of 1.3 micron. Nd ions are expected to substitute Bi ions in the lattice, and the local environment of them in this case is expected to be rather intricate. Since optical properties of rare earth ions are determined by the symmetry of local environment, it is interesting to investigate them in this crystal.

For complete characterization of optical properties of Nd ion in orthorhombic lattice the absorption spectra are to be measured, with light polarization parallel to crystallographic axes a, b and c. Because of the dimensions of the crystal sample in our disposal, it became possible to measure only two components with the polarization parallel to b and c axes. These spectra are presented in the following graphs.

a)



b)



c)

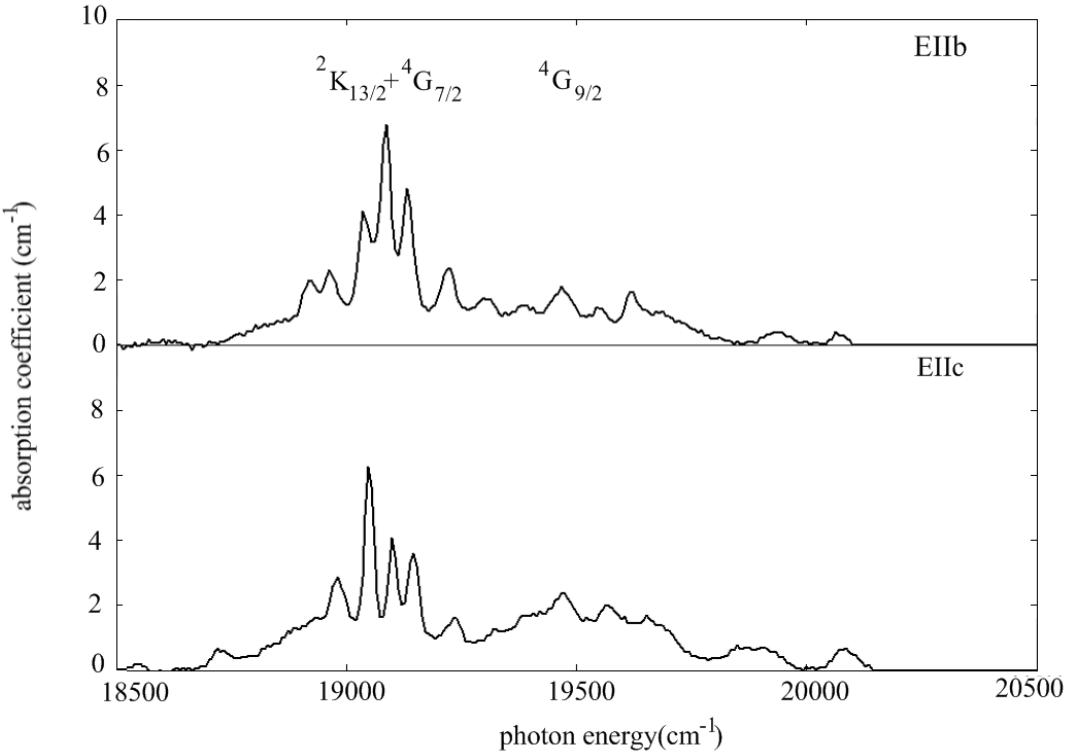


Fig. 1. Polarized absorption spectra of f-f transitions in Nd^{3+}:δ-BiBO single crystal at room temperature.

Besides, provisional observation of crystal structure suggests the hypothesis that the third component must not strongly differ from the two measured ones. So we have done the Judd-Ofelt analysis of spectra using only two components of absorption.

According to Judd Ofelt, the intensities of f-f transitions of an ion in a crystalline environment are connected with matrix elements of corresponding transitions in a free ion through three crystal field parameters $Omega_{2,4,6}$. We have found Omega parameters from absorption spectra using common Judd-Ofelt procedure. This procedure involves integration over the absorption profiles within separate manifolds solution of an overdefined system of linear algebraic equations, as presented here in vectorial form.

$$s = A\,\Omega. \qquad (1)$$

The values of Omega are presented in the table.

Table 1. Intensity parameters Ω_λ (10^{-20} cm^2), spectroscopic quality factors $X= \Omega_4/\Omega_6$ and lifetimes τ of the $^4F_{3/2}$ state in different crystals.

Compound	Ω_2	Ω_4	Ω_6	$X= \Omega_4/\Omega_6$	τ (μs)
δ-BiB_3O_6:Nd	6.898	3.921	11.495	0.341	517
$Nd_{0.5}Gd_{0.5}Fe_3(BO_3)_4$	4.4	8.04	8.25	0.97	496
$NdAl_3(BO_3)_4$	4.01	4.58	7.65	0.6	188
$NdAl_3(BO_3)_4$	6.07	9.14	14.58	0.627	98
$Nd:YAl_3(BO_3)_4$	3.09	5.04	3.11	1.62	302
$Nd:GdAl_3(BO_3)_4$	3.35	3.50	4.64	0.754	285
$Nd:Gd_{0.2}Y_{0.8}Al_3(BO_3)_4$	2.71	2.68	5.22	0.51	294
$Nd:Y_3Al_5O_{12}$	0.37	2.29	5.97	0.384	261
$Nd:Y_3Al_5O_{12}$	0.2	2.7	5	0.54	259
$Nd:YAlO_3$	1.3	4.7	5.7	0.82	157

The accuracy of the analysis can be illustrated by delta parameter showing the discrepancy between calculated and measured line strengths. In our case delta equals to 8.4 percent (we consider it a good result, especially in view of incomplete set of measured spectra).

Using obtained values of Omega, one can find the probabilities of transitions from upper lasing level, as well as branching ratios that show relative intensity of different stimulated transitions. There are four ones in Nd ion that start from $^4F_{3/2}$ level and terminate at $I_{9/2}$, $I_{11/2}$, $I_{13/2}$ and $I_{15/2}$ levels. These intensities depend only on $Omega_4$ and $_6$, so Kaminskii suggested introducing X factor being the ratio of them. Value of X in our crystal is 0.34, being the lowest value among the crystals cited in the table 3.

Thus I dare to conclude that delta BiBO is the most favorable for lasing to $I_{13/2}$, that is at 1.3 micron wavelength.